S-5/PHSH/CC-11/21

TDP (Honours) 5th Semester Exam., 2021

PHYSICS

(Honours)

ELEVENTH PAPER : (CC-11)

Full Marks : 60 *Time* : 3 Hours

The figures in the margin indicate full marks.

SECTION—A

1. Answer *any* **six** of the following questions : 2×6=12

(a) What is an observable?

(b) What does it physically mean by orthonormal condition?

(c) State Larmor's theorem.

(d) Why are symmetric diatomic molecules infrared-inactive?

(e) What do you mean by gyromagnetic ratio?

(f) Name a famous magnetooptical effect.

(g) Write two applications of Raman effect.

(h) What were the new ideas introduced in the vector atom model?

SECTION—B

(There are **four** questions from Question No. 2 to Question No. 5. Answer *either (a) or (b)* from each question.)

Answer the following questions : 3×4=12

2. *(a)* *(i)* Show that the momentum operator $\hat{p} = -i\hbar\frac{\partial}{\partial x}$ is Hermitian.

(ii) The wave function in $t = 0$, time is defined as $\psi(x,0)$. If the wave function is normalised, what will be the wave function at any arbitrary time t?

(iii) Calculate the commutator for position and linear momentum operator and hence show that $(xP_x - P_x x)\psi = i\hbar\psi$. 3+4+5=12

(OR)

(b) *(i)* Explain a wave function. What is its physical significance?

(ii) Explain the formation of Gaussian wave packet and show how it can express the propagation of wave.

(iii) Write the basic postulates of quantum mechanics.

(iv) Normalize the wave function $\psi = e^{ikx}$, $(0 \le x \le 2\pi)$ for the given limit. 2+4+3+3=12

3. *(a)* *(i)* For solving the hydrogen atom problem, why spherical polar co-ordinate are used?

(ii) Establish the Schrödinger equation for hydrogen atom in spherical polar co-ordinates. Solve the azimuthal part of the equation. From this, find the allowed values of the magnetic quantum number.

(iii) Find the expectation value of the energy when the state of a harmonic oscillator is described by the wave function

$$\psi(x,t) = \frac{1}{\sqrt{2}}\left[\psi_0(x,t) + \psi_1(x,t)\right]$$

where $\psi_0(x,t)$ and $\psi_1(x,t)$ are the wave functions for ground state and first excited state respectively. 2+(3+3)+4=12

(OR)

(b) (i) The radial part of the wave function for hydrogen atom in the ground state is given by $R = \frac{2}{a_0^{3/2}} e^{-r/a_0}$. Find the expression for ground state energy of hydrogen atom $(n = 1, l = 0)$.

(ii) A particle is trapped in a one-dimensional infinite potential well following the boundary condition

$v = 0$ for $0 < x < L$
$v = \infty$ for $x < 0$
$v = \infty$ for $x \geq L$

Establish the Schrödinger equation and draw the shape of the wave function for the ground and first excited state.

(iii) For the above condition, find the difference between the energy levels E_1 and E_3. 4+(3+3)+2=12

4. (a) (i) When the X-ray spectra are continuous and when are they discrete?

(ii) Establish Moseley's law from Bohr theory. Write the basic principle behind the Stern-Gerlach experiment and analyse the result of the experiment.

(iii) Find the possible values of j and m_j for the states in which $l = 3$ and $s = \frac{1}{2}$.

3+(3+2+2)+2=12

[Continued]

(OR)

(b) (i) What is space quantisation?

(ii) Considering the electron spin, explain the Zeeman effect in weak magnetic field. With a clear diagram find the number of splitting of energy levels from the state $^2P_{1/2}$ to state $^2S_{1/2}$.

(iii) Write the difference between the first and second order Stark effect.

2+(3+4)+3=12

5. (a) (i) Which of the following elements would you expect to have energy levels divided into singlet and triplet states?

Mg, Ne, Cl, Ca, Cu, Ag, Ba

(ii) According to Pauli's exclusion principle, what is the maximum number of electron in a subshell with a given l?

(iii) What are the possible states for a system of two electrons whose orbital quantum numbers are $l_1 = 1$ and $l_2 = 3$? Consider L-S coupling scheme. (Use spectroscopic notation.)

(iv) What will be the change in the rotational constant B when the hydrogen is replaced by deuterium in the hydrogen molecule? 3+1+5+3=12

[Turn Over]

(OR)

(b) (i) Write the difference between spectra of hydrogen atom and the alkali atomic spectra.

(ii) Explain Raman effect on the basis of quantum theory.

(iii) What do you mean by Stokes and anti-Stokes lines? What are the hot bands in vibrational spectra? 4+4+(2+2)=12

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S-5/PHSH/CC-12/21

TDP (Honours) 5th Semester Exam., 2021

PHYSICS

(Honours)

TWELFTH PAPER : (CC-12)

Full Marks : 60 *Time* : 3 Hours

The figures in the margin indicate full marks.

SECTION—A

1. Answer *any* **six** questions of the following : 2×6=12

(a) Write the difference between molecular bond and metallic bond.

(b) Explain the concept of lattices and basis.

(c) What is phonon? Write two important properties of it.

(d) Define mobility and conductivity.

(e) What is the importance of Hall effect?

(f) Write the difference between a super-conductor and a conductor cooled at 0 K.

(g) State Curie-Weiss law.

(h) What is the origin of piezoelectricity?

SECTION—B

(There are **four** questions from Question No. 2 to Question No. 5. Answer *either (a) or (b)* from each question).

2. (a) (i) Calculate the atomic packing fraction of f.c.c. cubic lattice.

(ii) Derive Laue's equation of diffraction of X-ray and obtain Bragg's diffraction condition from it.

(iii) Calculate the Bragg angle for X-rays having wavelength 1.64 Å in different order 2 and 3 if the interplanar spacing is 2.72 Å. 2+(4+3)+3=12

(OR)

(b) (i) What is reciprocal lattice? Why it is so named? Derive the expression for the primitive translation vectors of the reciprocal lattice.

[Continued]

(ii) Show that the reciprocal lattice to the b.c.c. is f.c.c. lattice.

(iii) What in atomic scattering factor? Explain its significance.

(iv) Find the interplanar distance between (1 1 1), (3 1 0) and (2 0 2) planes of lead. Given that lead has f.c.c. structure with atomic radius 1.75 Å.

(2+1+2)+3+2+2=12

3. (a) (i) Derive the dispersion relation for the lattice waves in a monoatomic linear lattice in terms of wave velocity. What are the allowed values of phonon wave vector?

(ii) Derive expression for the energy and momentum of phonon.

(iii) What discrepancy of Dulong and Petit's law was removed by Einstein?

(5+2)+3+2=12

(OR)

(b) (i) State the assumptions of Debye model of lattice specific heat and derive an expression for the lattice specific heat according to this model.

(ii) Obtain an expression for thermal conductivity of mental on the basis of free electron theory. (2+5)+5=12

[Turn Over]

4. *(a)* *(i)* Discuss Kronig-Penney model.

(ii) Using Kronig-Penney model, show that the energy spectrum of electron consists of a number of allowed energy bands separated by forbidden regions.

(iii) Derive a relation between mobility and Hall coefficient. 2+6+4=12

(OR)

(b) *(i)* Write the main characteristics of a superconductor.

(ii) Describe the effect of an external magnetic field on the superconducting state of a material and explain about Meissner effect related to it.

(iii) Write the difference between type-I and type-II superconductors. 3+(3+3)+3=12

5. *(a)* *(i)* What is ferromagnetism?

(ii) Discuss the Weiss field theory of ferromagnetism and explain how magnetic susceptibility varies with temperature.

(iii) What do you mean by orientational or dipolar polarisability? 1+(5+2)+4=12

(OR)

(b) *(i)* Write the difference between dia-, para- and ferro-magnetic materials.

(ii) Derive an expression for paramagnetic susceptibility of a paramagnetic material on the basis of classical Langevin's theory.

(iii) What do you mean by piezoelectric effect and pyroelectric effect? 3+5+4=12

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TDP (Honours) 5th Semester Exam., 2021

PHYSICS

(Honours)

PAPER : (DSE–I)

Full Marks : 80 *Time* : 3 Hours

The figures in the margin indicate full marks.

Candidates are required to give their answers in their own words as far as practicable.

SECTION—A

1. Answer *any* **eight** questions of the following : 2×8=16

(a) Define nuclear magnetic moment.

(b) What is the analogy between a nucleus and a liquid drop?

(c) What are magic and semimagic numbers in nuclear physics?

(d) How a cyclotron can be used to accelerate electron?

(e) What do you mean by reaction rate of a nuclear reaction?

(f) What do you understand by 'internal conversion'?

(g) What is 'mirror nuclei'? Give examples.

(h) What do you mean by fine structure of α-ray spectrum?

(i) Identify the unknown particle in the following reaction.

$$k^- + p \rightarrow k^+ + ?$$

(j) Explain the phenomenon of inverse β-decay.

(k) What is meant by range of α-particles?

(l) Define antiparticles with examples.

SECTION—B

There are four questions from Question No. 2 to Question No.5. Answer either *(a) or (b)* from each question.

Answer the following questions : 16×4=64

2. *(a)* *(i)* Explain the terms 'mass defect' and 'binding energy' of a nucleus.

(ii) Calculate the binding energy per nucleon for the deuteron. Given $m_n = 1.675\times10^{-27}$ kg, $m_p = 1.672\times10^{-27}$ kg, $m_D = 3.343\times10^{-27}$ kg, $c = 3\times10^8$ m/sec.

(iii) Write a short note on "electric quadrupole moment of the nucleus".

(iv) Explain the salient features of the liquid drop model. List out the various assumptions made while making the model. (3+4)+3+(3+3)=16

(OR)

(b) *(i)* Derive the expression for semi-empirical binding energy formula.

(ii) Using the semi-empirical binding energy formula, calculate binding energy of $^{40}Ca_{20}$.

(iii) Write a short note on the "size of the nucleus".

(iv) Explain the salient features of the shell model of the nucleus. How does it explain the magic numbers in the ground state of the nucleus? 5+2+2+(3+4)=16

3. *(a)* *(i)* State the condition of α-decay and explain why in a α-decay of a radioactive nuclide, the K.E. of the emitted α-particles is a little less than the disintegration energy.

(ii) "Electrons cannot exist as an integral part of the nucleus." Justify the statement.

(iii) Discuss how neutrino hypothesis explain the β-decay and β-ray energy spectrum.

(iv) Write the characteristics of γ-radiation. (4+2)+3+5+2=16

(OR)

(b) *(i)* Derive an expression for the Q-value of the reaction $X(a,b)Y$ in terms of K.E. of the incident and product particles and masses at the various particles and nuclei. Assuming the target nucleon to be initially at rest in the laboratory.

(ii) Discuss the compound nucleus theory at nuclear reactions.

(iii) The bombardment of lithium with protons gives rise to the reaction ${}^{7}_{3}Li + {}^{1}_{1}H \rightarrow {}^{4}_{2}He + {}^{4}_{2}He +$ Energy. The atomic masses of lithium, hydrogen and helium are 7.016 amu, 1.008 amu and 4.004 amu respectively. Find the value of energy released in this reaction.

[Continued]

(iv) Explain 'nuclear reaction cross-section'.

(iv) Define attenuation and absorption co-efficient of γ-ray when it passes through matter. (4+3)+3+2+2+2=16

4. *(a)* *(i)* Find the expression of momentum gained by the electron of the medium when a heavy particle is passing through the medium and interact with that electron.

(ii) Explain pair production and annihilation of electron-positron pair.

(iii) Explain the working principle of G-M counter with a neat diagram.

(iv) An ionisation chamber is connected to an electrometer of capacitance 0.5 pF and voltage sensitivity of 4 divisions per volt. A beam of α-particle causes a deflection of 0.8 divisions. Calculate the number of ion pair required and the energy of the α-particle. Given that 1 ion pair requires energy of 35 eV and $e = 1.6\times10^{-19}$ coulomb. 5+3+5+3=16

(OR)

(b) *(i)* What is Compton effect? Derive the expression for Compton Shift.

(ii) Write a short note on 'Cherenkov radiation'.

[Turn Over]

(iii) With a clear diagram explain the working principle of 'photomultiplier tube'.

(iv) α-particles of energy 5 MeV pass through an ionisation chamber at the rate of 10 per second. Assuming all the energy is used in producing ion pairs, calculate the current produced. (35 eV is required for producing an ion pair and e = 1.6×10^{-19} coulomb)

(1+4)+3+5+3=16

5. (a) (i) Describe the working principle of a Van de Graaff generator. Write its advantages as well as disadvantages.

(ii) Explain 'strangeness' and 'hypercharge' in connection with elementary particles.

(iii) Choose the reaction allowed or not

(1) $K^- + P \rightarrow \sum^- + \pi^+$

(2) $\bar{P} + P \rightarrow \pi^+ + \pi^-$

(4+3)+(3+3)+3=16

[Continued]

OR

(b) (i) What are elementary particles? Mention different types of elementary particles and their families.

(ii) With a neat sketch, discuss the principle and working of a cyclotron.

(iii) What are baryon numbers and strangeness numbers?

(iv) Write a short note on Quark model.

(1+4)+5+3+3=16

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TDP (Honours) 5th Semester Exam., 2021

PHYSICS

(Honours)

PAPER : (DSE–II)

Full Marks : 80 *Time* : 3 Hours

The figures in the margin indicate full marks.

SECTION—A

1. Answer *any* **eight** questions : 2×8=16

(a) Define linear vector space and give an example of this.

(b) Identify if the matrix $u = \frac{1}{\sqrt{2}}\begin{pmatrix} 1 & i \\ -i & -1 \end{pmatrix}$ is unitary or not.

(c) $A(p,q,r)B_r^{qs} = C_p^s$, here B_r^{qs} and C_p^s are tensors. What will be the nature of $A(p,q,r)$ i.e., is scalar, vector or tensor?

(d) Define a group.

(e) What is inner product and when an inner product space is called unitary space?

(f) Define *a priori* probability.

(g) What do you mean by linear dependence and independence of vectors?

(h) If a pair of dice is thrown, what is the probability that the sum of 8 shows?

(i) Define expectation and variance of random variable.

(j) What do you mean by basis of a vector space?

SECTION—B

(There are **four** questions from Question No. 2 to Question No. 5. Answer *either (a) or (b)* from each question.)

2. *(a)* *(i)* Solve the following equations in matrix method :

$$2x + 3y + z = 9$$
$$x + 2y + 3z = 6$$
$$3x + y + 2z = 8$$

(ii) Express

$$\begin{bmatrix} 1 & 2 & 3 \\ 3 & 4 & 5 \\ 5 & 6 & 7 \end{bmatrix}$$

as the sum of a symmetric and skew-symmetric matrix.

(iii) Show that eigenvalues of a Hermitian matrix are real.

(iv) Find the inverse of the following matrix :

$$A = \begin{pmatrix} 3 & 0 & -1 \\ 1 & 2 & 1 \\ 3 & 4 & 0 \end{pmatrix}$$

4+4+4+4=16

(OR)

(b) *(i)* Determine the characteristic roots and characteristic vectors of the following matrix :

$$B = \begin{bmatrix} 2 & 3 \\ 1 & 0 \end{bmatrix}$$

(ii) What is diagonal matrix? Diagonalize the following matrix :

$$A = \begin{bmatrix} -1 & -2 & 2 \\ 4 & 3 & -4 \\ 0 & -2 & 1 \end{bmatrix}$$

(iii) Show that Trace (AB) = Trace (BA)

(iv) State Cayley-Hamilton theorem. Hence find the inverse of the matrix :

$$\begin{bmatrix} 1 & 2 & 3 \\ 2 & -1 & 4 \\ 3 & 1 & 1 \end{bmatrix}$$

4+5+3+4=16

3. (a) (i) Show that the three-dimensional vectors

$$x^1 = (3, 0, 3)$$
$$x^2 = (0, 3, 0)$$
$$x^3 = (3, 0, 3)$$

are linearly independent.

(ii) Identify if the vector $(2, -5, 3)$ can be expressed as a linear combination of vectors

$$a_1 = (1, -3, 2)$$
$$a_2 = (2, -4, -1)$$
$$a_3 = (1, -5, 7)$$

If possible, identify if they are forming a linearly dependent or independent relation.

(iii) Define a tensor in 4-D space and from this, explain the rank of a tensor with example.

(iv) "The sum and difference of two tensors of the same rank results a third tensor of the same rank". Prove this.

3+(2+3)+(2+2)+4=16

(OR)

(b) (i) What do you mean by change of basis? Consider $\hat{A}$ and $\hat{B}$ are two linear operators in the vector space V. Write the basic rule to be followed by the linear operators $\hat{A}$ and $\hat{B}$.

(ii) Prove that if A^{μ} and B_{μ} are covariant and contravariant vectors, then $A^{\mu}B_{\mu}$ is invariant. What are Kroneckar alternating tensors?

(iii) Show that velocity is a contravariant tensor of rank one.

(iv) Prove that δ^p_q is a mixed tensor of second rank.

(v) If a tensor B^{pq} is symmetric in one coordinate system, show that it remains symmetric with respect to p and q in any coordinate system.

4+(3+1)+2+3+3=16

4. (a) (i) Explain character of representation with example.

(ii) What do you mean by centre of a group?

(iii) Write the basic properties of a group. Name two trivial subgroups of a group.

(iv) Define cyclic group and prove that every subgroup of a cyclic group is cyclic. What is permutation group?

(v) What is a set?

3+2+(2+2)+(3+2)+2=16

(OR)

(b) (i) Show that in a group $(G, \circ)$ every element possesses a unique inverse.

(ii) What is irreducible representation? When a representation T is said to be fully reduced?

(iii) When is mapping called external binary operation? Write some properties of binary operation.

(iv) If $(G, \circ)$ be a group and $a^2 = e \forall a \in G$, then show that the group must be commutative. 4+(2+2)+(2+3)+3=16

5. (a) (i) Explain the terms conditional probability and variance.

(ii) Find the expected number of heads when n coins are tossed.

(iii) Prove that for any two events A and B, the probability that either A or B or both occur can be given by

$$P(A \cup B) = P(A) + P(B) - P(A \cap B)$$

(iv) In a sum of $2n$ observations, half of them are equal to a and remaining half are equal to '$-a$'. If SD = 2, find $|a|$.

4+4+4+4=16

(OR)

(b) (i) Define mean, median and mode.

(ii) For any two events, such that $A \subseteq B$, then prove $P(A) \leq P(B)$.

(iii) Mean of 100 items is 49. It was found that three terms which should have been 60, 70, 80 were wrongly read as 40, 20 and 50 respectively. Find the correct number of mean.

(iv) What is normal distribution or Gaussian distribution? Write the probability function and draw the distribution curve. 4+4+4+4=16

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